A Survey on Wood Recognition Using Machine Vision

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Abstract

Wood recognition is an important issue that has been presented in many industrial enterprises such as the furniture industries and the wood panel production. Recently, research activities in this area have put the emphasis on the use of machine vision. Given one or more wood images, a wood recognition method can recognise or classify a wood sample into a certain wood specie. In this paper, the basic concepts and the development process of wood recognition have been introduced at first. Then, wood recognition methods were presented on three levels, i.e. wood image classification, method of feature extraction, classifier chooses. Finally, the future works in this area has been pointed out.

Keywords

Wood Recognition; Machine Vision; Feature Extraction; Classifier

Introduction

The wood recognition is an important issue present in many industrial enterprises such as the furniture industries and the wood panel production. Different woods have distinct aspects, properties, and costs. The correct recognition of the wood type is very important to guarantee that the final product has the required features and characteristics. For example, in the production of wood panels, the wood type influences the quantity of the glue that must be used in the panel to guarantee the proper mechanical properties. On the other side, the glue has a great impact on the total cost of the panel and effects the overall environment. In the paper industry, the wood type influences the final quantity of the cellulose of paper, and consequently, the quality of the paper (Wang Bihui, 2010).

The early method of wood recognition is mainly based on experience and expertise, according to macroscopic features and microscopic characteristics, through observation, comparison and analysis to recognize wood gradually, which has several disadvantages, such as predominatesubjective elements, low recognition rates, time- consuming and so on. In recent years, wood recognition assisted by computer technology has become a mainstream method. Currently, machine vision researches based on wood microstructure or stereogram images is widely spread (Sun Lingjun, 2011).

In this paper, related works on wood recognition will be introduced using machine vision in Section 2, among which, the classification of wood sample images has been illustrated in Section 2.1.1; and then the wood feature extraction metheds were depicted in Section 2.1.2; followed by the examination of the classifier design for wood recognition in Section 2.1.3. In section 3, the current and future developments of wood recognition have been reported.

Wood Recognition Using Machine Vision

Most of the wood identification methods using machine vision usually consist of three steps: wood images obtaining, feature extraction, and classifier design, as shown in Figure 1. Wood image as the object of wood identification method using machine vision is divided into macroscopic image and microscopic image. Accordingly, feature extraction also is divided into macroscopic feature extraction and microscopic feature extraction. And then the type of classifier is selected according to the different characteristics.

Wood Sample Image Classification

Artificial identification of wood can be made by macroscopic and microscopic observation of wood in two ways, and tree species are determined according to its corresponding anatomical features. Similarly, computer recognition based on wood image according to different wood data acquisition object, is divided into based on macro wood texture and microstructure of two kinds of methods. In addition, the way is based on the micro structure need with the help of the corresponding microscopic image acquisition equipment. Depending on different equipment, wood

images can be further divided into stereogram, biological microscopic images and scanning electron microscope images, as shown in Figure 2. Among them, biological microscopic images requir wood slicing, which is more clear but tends to lift the price. Regardless of macroscopic or microscopic wood images, they are choiced as a subject for study in some wood papers of classification and recognition.

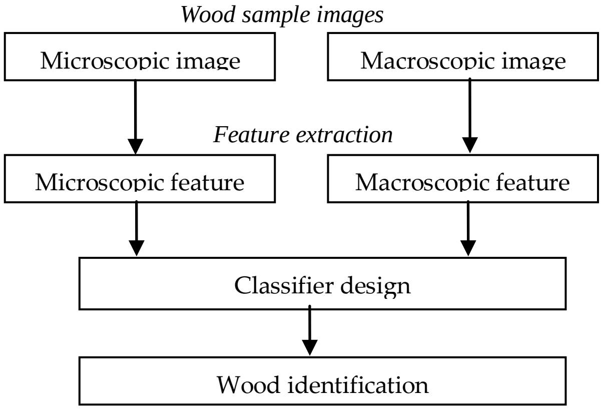

FIG. 1 WOOD IDENTIFICATION PROCESS

(a) (b) (c)

FIG. 2 WOOD MICROSCOPIC IMAGE (a) STEREOGRAM (b) BIOLOGICAL MICROSCOPIC IMAGES (c) SCANNING ELECTRON MICROSCOPE IMAGES

Wood Image Feature Extraction Techniques

Different sample images show different characteristics of wood, so the feature extraction methods are varying. There are many papers which introduce many wood image feature extraction methods, then according to different classification of object of study, this paper will introduce wood image feature extraction techniques.

Microscopic Feature Extraction

Microscopic feature extraction usually needs image segmentation which refers to the process of partitioning a digital image into multiple segments (sets of pixels). The goal is to analyze a part of the image only over the whole image, to infer more accurately. The focus is on the shapes and distribution of tracheids in the pictures for most of these papers, to segment the image in such a way to get only those parts of the micrographs. There are many methods of segmenting an image like thresholding, edge detection etc.

Abhirup Mallik, etc.(2011)classified wood species using scanning electron microscopy (SEM) micrographs obtained with 1500× magnification and processed by image segmentation. The results showed that differences can be observed among species in the wood texture at this magnification. The micrographs have been processed in a simple way using segmentation which contains thresholding and edge detection and object recognition to identify the cross-section tracheids belonging to earlywood of seven different timber species: Fagus sylvatica, Castanea sativa, Juglans regia, Eucalyptus globulus, Hymenaea courbaril, Pinus silvestris and Pinus radiata. Then the shape, number and distribution of the tracheids have been analysed on five features: circularity, rectangularity, number of tracheids, distance between tracheids and average area.

Wang Hangjun, etc.(2011) introduced a novel method of softwood species automatic computer recognition through cross-sectional microscopic images proposed in this paper. The method extracts PCA (principle component analysis) feature of wood images, and generates “EigenTrees”. Principle component analysis (PCA), a kind of classic linear data dimension reduction method, in the sense of minimum mean square error with less dimension according to the original data, has the characteristics of simplicity and efficiency. Turk, etc. propose EigenFaces, firstly to apply PCA to face recognition of the image, has become a classic in the field of the whole image and pattern recognition widely used in dimension reduction in computer vision.

Wang Hangjun, etc.(2012) depicted Level Set conducted in the segmentation of wood images. After the combination of the edge-based and region-based models in Level Set, they introduced the local information in image to improve the image segmentaion performance for the wood tissue’s inhomogeneity and reduce the noise caused by the production of wood specimens. Then, an area threshold is used to get rid of blisters and other impurities in the image to obtain the wood pores at last.

Ji Zhiwei, etc.(2011) proposed a morphological feature extraction method of wood pores based on an improved growing region algorithm. By this method, precise segmentation of wood pore cells from micrographs can acquire ten morphological features of pore cells according to the technology of chain codes tracking, which can be validated in six kinds of micrograph of broadleaf wood. The simulation experiment has shown that this algorithm could

improve the computational speed of segmentation of wood pores. Meanwhile, the ten morphological features of pore cells have a quite distinguishable capacity in the six kinds of broadleaf wood. It is suggested that the algorithm proposed is highly applicable to artificial broadleaf species recognizing.

Sun Lingjun, etc.(2011) put forward a automatic wood recognition through wood stereogram which can be obtained conveniently. Firstly, a standardized preprocess of wood images was carried out. Secondly, block local binary pattern (LBP), used to describe the local texture feature of image, was selected to extract wood features. In this paper, the best recognition rate is above 93%.

Qi Hengnian, etc.(2008) introduced a method based on an analysis of quantitative pore feature, which differs from traditional qualitative methods, by means of mathematical morphology methods such as dilation and erosion, open and close transformation of wood cross-sections, image repairing, noise filtering and edge detection to segment the pores from their background. Then the mean square errors (MSE) of pores were computed to describe the distribution of pores.

Ma Linjin, etc.(2012) proposed a new method for wood recognition based on texture analysis. At first, wood texture images were divided into several blocks in our method. Secondly, wood features were extracted from these blocked grey-scale images using different mask, knows as higher-order local auto correlation (HLAC). Experiments carried out on the wood texture database have demonstrated that our method outperforms the original HLAC method.

Sun Lingjun, etc.(2011) described wood recognition method based on texture analysis which was presented in this paper. Firstly, the sample images were divided into several regions after cutting from wood stereogram images. Then, more features were extracted by Gabor Wavelets through five scales and eight orientations. To gain the key points of these Gabor features, clustering and sifting operation were used to dislodge the dimmed features extracted from the noise regions, such as cleavage region, resin canal region and so on.

Xu Tianlong, etc. (2011) intruduced the influences that different histogram matching algorithms have on identifying the softwood. The experiment partitioned images in three different ways of early wood-late wood transition, early wood, and randomization, and extracted the PCA(Principle Component Analysis) features of these wood images separately. Histogram matching algorithm was divided into two categories, bin-to-bin and cross-bin, then experiments were conducted on wood recognition by four different histogram matching algorithms of the Euclidean, Chi-Square, EMD and Quadratic-Chi. The experimental results indicated that the histogram matching algorithms of cross-bin have positive effect on wood recognition, especially the quadratic-Chi distance put forward recently.

Wang Hangjun, etc.(2009) proposed an adaptive method to evaluate the parameter of optimal closed region area, which is a step towards this goal. Their method sorted all closed regions according to area size after image segmentation; then use maximum utilized between-class variance to divide closed region into two classes like the Otsu' algorithm handle gray scale histogram. The method based on genetic algorithm has overcome the Otsu algorithm's drawback of time consuming.

Wang Hangjun, etc.(2012) put forward a wood recognition method based on Gabor entropy. According to the characteristics of the wood stereogram, a method of image ormalization has been presented firstly. Then wood texture features were extracted using Gabor wavelet and the best scale and orientation parameters were also analyzed. In addition to the mean and standard deviation on the Gabor filter bank, entropy, contrast and other statistical features were used for classification. Experimental results showed that the entropy can better extract texture features on Gabor wavelet, which greatly improved the wood recognition rate.

Wang Bihui, etc.(2010) intruduced a wood recognition method based on Grey-Level Co-Occurrence Matrix(GLCM). Under the image resolution of 100*100, four directions, i.e. 0°, 45°, 90°, and 135°, were severed as the generated pixel directions of GLCM. Besides, providing the pixel interval with 4 and gray level with 128; as well six features, Energy, Entropy, Contrast, Dissimilarity, Inverse Difference Moment, and Variance, were used as classification features in the experiment.

Feature Extraction

The wood microscopic feature, such as pores, parenchyma, etc., has been demonstrated blurs in wood macroscopic images. Therefore, the macroscopic feature usually is the overall feature of the wood

macroscopic image which includes color feature and texture feature.

1) Color Feature Extraction

Yang Shaochun, etc.(2007) and Dai Tianhong, etc.(2006) intruduced a method to extract Lab color feature of wood image. With the characteristic of isometry and high resolving power, Lab uniform color space is much suitable to measure and compare the little differences in color. The wood color is distributed at a narrow range in color space, so it is propitious to compare and plot out them if the color feature is fully utilized in Lab color space to express the wood surface color. In this color space, the color features of five tree species have been extracted for classification, and the result was satisfactory.

Wang Hui, etc.(2009) proposed a method to extract RGB color feature of wood image. They used three colors in RGB color space coordinate, and each coordinate axis includes three color moment coupled with the two whole image mean and variance. Then these 11 parameters were regarded as characteristic of color on image processing and classification.

In order to determine whether the color space is appropriate for wood species recognition, Wang Hui, etc.(2009) extracted color histogram and color moment features of wood samples obtained from RGB, HSV, Lab, I1I2I3 and normalized T, five commonly used color spaces, respectively and the recognition experiments were carried out. The results showed that HSV color space is most suitable for the recognition of wood species.

2) Texture Feature Extraction

Yu Haipeng, etc.(2007) introduced a method of timber tree species for quick retrieval and identification based on textural features of wood images, by the adoption of the textural features of wood images as color, grey and texture of wood images, and measured with nine parameters: hue, saturation, illuminance, contrast, angular second moment, sum of variances, long run emphasis, fractal dimension, and wavelet horizontal energy proportion, then retrieval of wood species was performed according to maximal similarity theory.

Bai Xuebing, etc.(2005) classified wood by Gray Level Co-occurrence Matrix (GLCM) of wood surface texture. In this method, wood texture parameters of Gray Level Co-occurrencen Matrix (GLCM) were selected by relevance analysis. The results showed that GLCM parameters "Angu lar SecondMoment", "contrast ", "correlation", "entropy", "sum of squares" and "inverse difference moment" are suitable to describe the wood teture and the best pixels interval when GLCM built is four and the wood image size is 512 * 512 and proportion is 1:1, and 128 levels image gray can best reflect the wood texture in formation.

Wood Image Feature Classifier

TABLE 1 WOOD RECOGNITION USING MACHINE VISION

Author	Wood Image	Feature	Classifier
Abhirup, etc.	scanning electron microscope images	circularity, rectangularity, number of tracheids, distance between tracheids and average area	LDA, Quadratic classification, Logistic regression, KNN, Bayes inference, SVM and NN
Wang, etc.	biological microscopic images	PCA feature	KNN and SVM
Wang, etc.	biological microscopic images	wood pore feature	
Wei, etc.	biological microscopic images	the morphological features of pore cells	SVM
Sun, etc.	stereogram	LBP feature	KNN
Qi, etc.	biological microscopic images	pore feature	
Ma, etc.	stereogram	HLAC feature	SVM
Sun, etc.	stereogram	Gabor Wavelets feature	KNN
Xu, etc.	biological microscopic images	PCA feature	
Wang, etc.	biological microscopic images	image segmentation size	
Wang, etc.	stereogram	Gabor wavelet feature	
Wang, etc.		GLCM feature	SVM
Yang, etc.	Macroscopic image	Lab color feature	NN and KNN
Wang, etc.	Macroscopic image	RGB color feature	BPNN
Wang, etc.	Macroscopic image	color histogram and color moment feature	
Yu, etc.	Macroscopic image	textural feature	maximal similarity theory and limen discriminance
Bai , etc.	Macroscopic image	GLCM feature	Hamming BPNN

Now, the classifiers applied to the wood identification are the mature and widely used classifiers, such as

linear classifier, Quadratic classifier, Logistic regression, K-nearest neighbors algorithm, Bayesian inference, Support vector machine, Neural network as shown in Table 1.

linear classifier: In the field of machine learning, the goal of statistical classification is to use an object's characteristics to identify which class (or group) it belongs to. A linear classifier achieves this by making a classification decision based on the value of a linear combination of the characteristics.

Quadratic classifier: A quadratic classifier is used in machine learning and statistical classification to separate measurements of two or more classes of objects or events by a quadric surface. It is a more general version of the linear classifier.

Logistic regression: In statistics, logistic regression or logit regression is a type of regression analysis used for predicting the outcome of a categorical dependent variable based on one or more predictor variables. It is used in estimating empirical values of the parameters in a qualitative response model.

K-nearest neighbors algorithm: In pattern recognition, the k-nearest neighbor algorithm (k-NN), a non-parametric method to classify objects based on the closest training examples in the feature space, is a type of instance-based learning, or lazy learning where the function is only approximated locally and all computation is deferred until classification.

Bayesian inference: In statistics, Bayesian inference is a method of inference in which Bayes' rule is used to update the probability estimate for a hypothesis as additional evidence is learned. Bayesian updating is an important technique throughout statistics, and especially in mathematical statistics.

Support vector machine: In machine learning, support vector machines (SVM) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. The basic SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the output, making it a non-probabilistic binary linear classifier.

Neural network: A neural network (NN), in the case of artificial neurons called artificial neural network (ANN) or simulated neural network (SNN), is an interconnected group of natural or artificial neurons that uses a mathematical or computational model for information processing based on a connectionistic approach to computation. In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network.

Abhirup Mallik, etc.(2011) classified the extracted features using different statistical methods: Linear Discriminant Analysis (LDA), Quadratic classification, Logistic regression, K Nearest Neighbors (KNN), Naïve Bayes, Support Vector Machines (SVM) and Neural Networks. Wang Hangjun, etc.(2011) utilized classification algorithms of the nearest neighbor and SVM to identify Soft wood. Ji Zhiwei, etc.(2011) built six SVM classifier to verify the method to extract the 10 morphological classification ability. Sun Lingjun, etc.(2011) developed KNN classifier to verify the method and compared recognition rates in different distances. Ma Linjin, etc.(2012) used Support Vector Machine (SVM) to verify the performance of the method. Sun Lingjun,, etc.(2011) classified Gabor Wavelets feature through the nearest neighbor classifier. Wang Bihui, etc.(2010) has acquired about 91.7% recognition rates through feature extractions of 24 wood species, and 480 samples, and the use of the SVM classifier. Yang Shaochun, etc.(2007) and Dai Tianhong, etc.(2006) employed KNN and BPNN to classify LAB color feature of wood image. Dai Tianhong, etc.(2006) used BPNN to classify RGB color feature of wood image. Wang Hui, etc.(2009) performed retrieval of wood species according to maximal similarity theory and limen discriminance. Bai Xuebing, etc.(2005)used Hamming BPNN to verify the accuracy of the wood image classification.

Current & Future Development

As it can be seen from the above reviewed in section 2that wood recognition using machine vision has already been well studied by many researchers. According to different wood images including macroscopic images and Microscopic image, the different identification features and design classifier are extracted to verify the accuracy of the wood image classification. There are many method of wood recognition which can get higher recognition rate. It is important for researchers and developers to realize that the selection of wood features of the images can play a very significant role in enhancing the quality of the recognition results.

However, most wood recognition method using machine vision has not been popularization and application. There are the following several reasons:

1) There are many different kinds of wood, and it is difficult to use a method to identify all kinds of wood.

Identification methods of all the literatures only classfy several kinds of wood.

2) Although microscopic image recognition rates are always higher, they require expensive equipment or complex process.

Therefore, the future development of wood recognition will be close to traditional wood identification which combines with the visual, smell, touch, taste and so on. This will need the involvement of a variety of sensors, to get different sensor data, and extract the features and using sensor fusion technology to obtain a high-efficiently and accurately identified wood.

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REFERENCES

Abhirup Mallik, Javier Tarrío-Saavedra, Mario Francisco-Fernández, Salvador Naya. "Classification of Wood Micrographs by Image Segmentation." Chemometrics and Intelligent Laboratory Systems 107(2011): 351–362.

Bai Xuebing, Wang Keqi, Wang Hui. "Research on the classif ication of wood texture based on Gray LevelCo-occurrenceMatrix" Journal of Harbin Institute of Technology 37(2005): 1667–1670.

Dai Tianhong, Wang Keqi, Bai Xuebing, Hen Lijun, Xie Yonghua. "Analysis of Wood Classification Based on Neural Network and Color Feature." Forestry Engineering 22(2006): 18–22.

Ji Zhiwei, Wang Hangjun, He Tao, Yin Jianxin. "A Morphological Feature Extraction Method of Wood Pores Based on an Improved Growing Region Algorithm." Journal of Beijing Forestry University 33(2011): 64–69.

Ma Linjin, Wang Hangjun. "A New Method for Wood Recognition Based on Blocked HLAC." Paper presented at Eighth International Conference on Natural Computation, Chongqing, China, May 29–31, 2012.

Qi Hengnian, Chen Fengnong, Wang Hangjun. "Analysis of Quantitative Pore Features Based on Mathematical Morphology." Forestry Studies in China 10(2008): 193–198.

Qi Hengnian, Zhang Guangqun, Li Wenzhu, Wang Hangjun. "An Automatic Method of Tree-Rings Boundary Detection on Wood Micro-images." Paper presented at International Conference on Computer Application and System Modeling, Taiyuan, China, October 477–480, 2010.

Sun Lingjun, Wang Hangjun, Qi Hengnian. "Wood Recognition Based on Block Local Binary Pattern (LBP)." Journal of Beijing Forestry University 33(2011): 107–112.

Sun Lingjun, Ji Zhiwei, Wang Hangjun. "A New Wood Recognition Method Based on Texture Analysis." Applied Mechanics and Materials 58-60(2011): 613–617.

Wang Bihui, Qi Hengnian. "Wood Recognition Based on Grey-Level Co-Occurrence Matrix." Paper presented at International Conference on Computer Application and System Modeling, Taiyuan, China, October 269–272, 2010.

Wang Hangjun, Qi Hengnian, Li, Wenzhu, Zhang Guangqun, Wang Paoping. "A GA-Based Pore Feature Automatic Extraction Algorithm." Paper presented at In Proceedings of the First ACM/SIGEVO Summit on Genetic and Evolutionary Computation, Shanghai, China, June 985–988, 2009.

Wang Hangjun, Wang Bihui. "A Novel Method of Softwood Recognition." Scientia Silvae Sinicae 47(2011): 141–145.

Wang Hangjun, Qi Hengnian. "Segmentation Method of Wood Microscopic Image Based on Local Level Set." Journal of Image and Graphics 17(2012): 236–240.

Wang Hangjun, Qi Hengnian, Wang Xiaofeng. "A New Wood Recognition Method Based on Gabor Entropy." Paper presented at Advanced Intelligent Computing Theories and Applications: With Aspects of Artificial Intelligence, Changsha, China, August 435–440, 2012.

Wang Hui, Lu Yan, Zhang Kai. "Research on Color Space Applicable to Wood Species Recognition" Forestry Machinery & Woodworking Equipment 37(2009): 20–22.

Xu Tianlong, Wang Hangjun, Sun Lingjun. "Wood Recognition Based on Histogram Matching Algorithms." Applied Mechanics and Materials 58-60(2011): 1744–1748.

Yang Shaochun, Wang Keqi, Dai Tianhong, Bai Xuebing. "Analysis of Wood Classification Using L*a*b* Color Space." Forestry Machinery & Woodworking Equipment 35(2007): 28–30.

Yu Haipeng, Liu Yixing, Liu Zhenbo. "Wood Species Retrieval on Base of Image Textural Features" Scientia Silvae Sinicae 43(2007): 77–81.